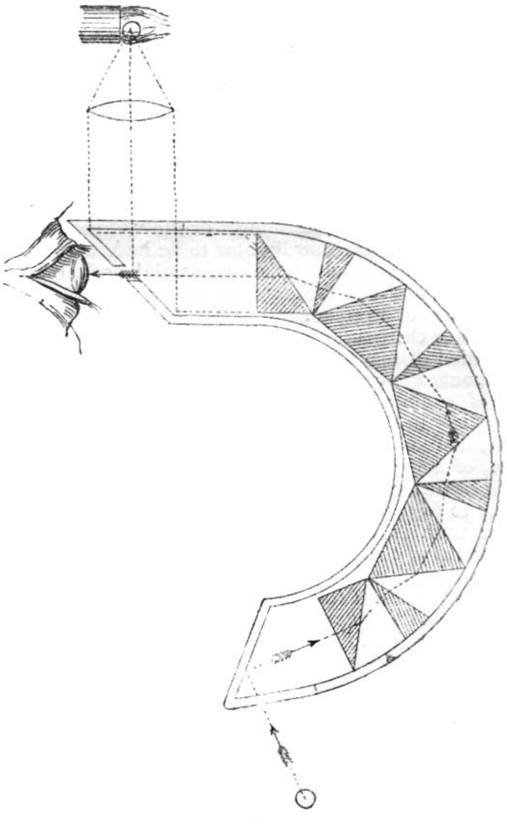
slight one, and we fear it is still on the increase. "Unless," said Mill, "individuality shall be able to assert itself against the yoke of public opinion, Europe, notwithstanding its noble antecedents and its professed Christianity, will tend to become another China." Prof. Müller would persuade us that our Universities are a safeguard against this catastrophe. But when China is mentioned in connection with education, examinations are suggested by an irresistible association. If, therefore, England is to escape the fate of China, it is not only encouraging to reflect that the most conspicuous modern building in Prof. Müller's own University is the new Examination Schools.

DESCRIPTION OF AN INSTRUMENT FOR EXPLORING DARK CAVITIES WHICH ARE INACCESSIBLE TO DIRECT LIGHT

AN electric lamp has recently been proposed for surgical and dental operations.[1] Some years ago I designed an instrument for illuminating the dark cavities of the body which would, I think, be very serviceable in connection with an electric lamp.

This instrument consists of a series of prisms arranged somewhat as in the corona employed for spectrum analysis. The accompanying woodcut will be sufficiently intelligible without any detailed description. The different prisms are of glass of such refractive indices as to secure achromatism, and the rays of light are bent round corners, so as, finally, to reach an external observer.



In most cases one or two such prisms will be sufficient, but any number may be employed so long as the loss of light from absorption, superficial reflection, and other causes is not so great as to defeat the object in view by destroying the distinctness of the image.

THOMAS STEVENSON

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[1] *Engineer*, March, 1879.

IMPROVEMENTS IN BLEACHING

A METHOD of applying the ordinary bleaching agents (hypochlorites) in a new way has been invented by Count Dienheim de Brochocki of Paris. Instead of immersing the goods to be bleached in an ordinary "chloride of lime" vat, and subsequently souring, the inventor treats bleaching-powder with an acid and simultaneously passes air through the mixture, so that chlorine and hypochlorous acid vapours are mechanically carried off; the resulting gases are passed through an alkaline solution in such proportions as to saturate part or the whole of the alkali, or to supersaturate it at will. The resulting liquid is said to be sufficiently stable to be kept without change for two or three months; it can readily be prepared of a density of 30° Beaumé, and acts as a bleacher without requiring any acidulation, and for many purposes is said to be superior to the ordinary bleaching-vat.

To this liquid the fanciful name "chlorozone" has been given, the inventor asserting that the oxidising power of a given quantity of bleaching-powder is *increased* by this treatment through the fixation in the product of some of the oxygen of the air used as carrying agent; the which oxygen he conceives to be liberated in the form of ozone in contact with the goods to be bleached! Although no experimental proof of the truth of this somewhat novel proposition appears to have been vouchsafed to the scientific world, yet it would seem that the new product has at least some practical advantages over the older bleaching agents, as it is used to a considerable extent in Paris, whilst works for its manufacture on a large scale have been recently erected at Warrington by Messrs. Nath. Holmes and Partners.

HERING'S THEORY OF THE VISION OF LIGHT AND COLOURS[1]

III.

IN the sixth and last memoir the author develops the part of his theory which has probably excited the most interest, namely, that of the vision of *colours*. He devotes his first section to the *mode of classification* of colours, and as this is not only the most important part, but differs materially from the generally received views, it is desirable to give its substance pretty fully.

He explains that, as he has based his general theory on what are naturally and physiologically two simple sensations, white and black, so he proposes to base his treatment of colours on the "natural system of colour-sensations." He then has to seek what the simple natural sensations of colour are, neglecting in this classification all consideration of the physical properties usually connected with them. He inquires, therefore, what simple colour-sensations there are. Taking the six usually admitted, violet, blue, green, yellow, orange, and red, he finds that two, namely, violet and orange, are obviously compound sensations; for in violet of every hue there can be distinguished clearly a mixture of the two sensations, blue and red; and similarly in orange there can always be traced the elements of red and yellow. The other four colours are red,[2] green, blue, and yellow. None of the sensations known by these names contain, when pure, any semblance of another colour-sensation. These four, therefore, may with perfect correctness, as was pointed out by Leonardo da Vinci, be considered as simple or fundamental colour-sensations. On this account they have received special names, not borrowed from any coloured natural objects.

All other colour-sensations than these may be called mixed or compound sensations, as two elements can always be discovered in them; but it is a fixed principle that *more than two simple colours* can never be evident in the same mixture.

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[1] Continued from vol. xx. p. 639.

[2] This, however, is not the spectral red, which contains a mixture of yellow.

There is also a natural peculiarity in the capabilities of the various simple colours for combining with each other. Red will combine with yellow or blue, but not with green, *i.e.*, red and green can never be both distinguished in the same combinations. Similarly, yellow will combine with red or green, but not with blue. Green will combine with blue or yellow, but not with red; and blue will combine with red or green, but not with yellow. In other words, we find the natural law that *on the one hand Red and Green*, and *on the other hand Blue and Yellow*, are never visible together in the same combination; they are incapable of combining together. What the cause of this is it is impossible to say. It is customary in books on physics to say that red and green, or blue and yellow combined, make white; but this is only true when by red, green, &c., are meant ether vibrations, and not physiological sensations; for to insist that red *plus* green makes white in the same sense that red *plus* blue makes violet would be contrary to common observation, for in pure white there is no trace of any colour-sensation whatever. It must, therefore, be something in the natural connection of these colours with our sense of vision that makes these combinations incompatible with each other; and for the sake of using a short expression for this relation, the author proposes, in consideration of their so-to-speak inimical relations to each other, to call red and green, or blue and yellow *opposite*, or *contrary*, or *antagonistic colours* (*Gegenfarben*).[1]

The combination of any simple colour-sensation with that of another (not antagonistic) gives a sensation of a different *hue* (*Farbenton*), and the hue will vary according to the proportions of the components. Thus different proportions of red and blue will give different hues of violet, and so on. The whole scale of these may be conveniently expressed by a "colour circle." Divide a circle into four quadrants, and at each point of division put one of the four simple colours, arranging the antagonistic ones diametrically opposite to each other. The intermediate portions may then be filled in with compound hues, passing in regular gradations from one of the simple colours to the next adjoining on either side. Such a circle, if supposed to be divided into very minute gradations, will contain all possible hues of colour. And every *hue, both simple and compound, will have, diametrically opposite to it, its natural antagonistic colour.*[1] Now every possible hue of colour may appear in many different states of "purity," or, as it is often called, "saturation." These various states are called by the author "nuances," and they are caused by the mixture with the hue in question of various proportions of black and white, *i.e.*, various degrees of the black-white sensation. Thus red may be mixed with black, white, medium gray, light gray, or dark gray, every grade giving a different nuance of the red hue.[2] The different hues and the different nuances of each taken together will comprise all colour-sensations possible.

The pure colour-sensations are unknown to us; what we experience are always nuances containing white or black. The fact that some colours, and some parts of the spectrum, appear so much brighter than others is due, the author asserts, to the fact of the former containing more white. He conceives that if the pure colour-sensations alone could be experienced they would all be of equal brilliancy, and would probably have the same degree of luminosity as the medium gray; for as each colour-sensation must be considered as an independent one, there is no reason for attributing to any of them the particular effect that we are accustomed to connect with whiteness in particular.

The varieties of colour-sensation admit of being expressed in a formula. Varieties of hue may be expressed by the proportions of each colour they contain; thus $\frac{\text{Blue}}{\text{Red}}$ or $\frac{\text{Red}}{\text{Blue}}$ will express all varieties of violet; the *blueness* of it will $= \frac{\text{Blue}}{\text{Blue} + \text{Red},}$ and the *redness* $= \frac{\text{Red.}}{\text{Blue} + \text{Red.}}$

The nuance of a hue, or its degree of purity, is expressed by the ratio the weight of the pure colour-sensation bears to the whole weight of the combination; thus the purity of a nuance of Blue $= \frac{\text{Blue}}{\text{Blue} + \text{White} + \text{Black}}$.

Thus, suppose a red is mixed with double its weight of medium gray, then there are equal weights of each sensation, and the purity will be

$$= \frac{1}{1+1+1} = \frac{1}{3} = 0{\cdot}33.$$

For a compound hue, for example, violet, the purity will be $= \frac{\text{Blue} + \text{Red}}{\text{Blue} + \text{Red} + \text{Black} + \text{White}}$. For example, suppose the weight of the blue and red sensations are 4 each, the white 1, and the black 3, forming a dark nuance of violet, the purity

$$= \frac{4+4}{4+4+1+3} = \frac{8}{12} = 0{\cdot}66.$$

The author further forms an estimate of the *brightness* or *luminosity* (*Helligkeit*) of a nuance by the formula

$$\frac{\text{White} + \frac{1}{2}\,\text{Colour}}{\text{White} + \text{Black} + \text{Colour}}.$$

Thus in the former of the above two examples, the luminosity will be

$$= \frac{1+\frac{1}{2}}{1+1+1} = \frac{1}{2}.$$

In the latter

$$= \frac{1+\frac{8}{2}}{1+3+8} = \frac{5}{12}.$$

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[1] The following observations of Sir John Herschel (extracted from his Report on my paper on Colour Blindness, presented to the Royal Society in 1856) strikingly confirm the views expressed by Herr Hering:—

"It is as necessary to distinguish between our sensations of colour and the qualities of the light producing them, as it is to distinguish between bitterness, sweetness, sourness, saltness, &c., and the chemical constitution of the several bodies which we call bitter, sweet, &c. Whatever their views of prismatic analysis or composition might suggest to Wollaston and Young, I cannot persuade myself that either of them recognised the *sensation* of greenness as a constituent of the sensations they received in viewing chrome yellow or the petal of a marigold on the one hand, and ultra-marine, or the blue salera, on the other; or that they could fail to recognise a certain redness in the colour of the violet, which Newton appears to have had in view when he regarded the spectrum as a sort of octave of colour, tracing, in the repetition of redness in the extreme refrangible ray, the commencement of a higher octave too feeble to affect the sight in its superior tones. Speaking of my own sensations I should say that in fresh grass or the laurel leaf, I do not recognise the sensation either of blue or yellow, but something *sui generis*; while on the other hand I never fail to be sensible of the presence of the red element in either violet or any of the hues to which the name of purple is indiscriminately given; and my impression in this respect is borne out by the similar testimony of persons, good judges of colour, whom I have questioned on the subject

"It seems impossible to reason on the joint or compound sensation which ought to result from the supra-position in the sensorium of any two or more sensations which we may please to call primary.

"Declaring red and green to be primary sensations, and yellow a mixture of them [is] a proposition which needs only to be understood to be repudiated—quite as decidedly as that the *sensation* of greenness is a mixture of the *sensations* of blueness and yellowness, and for the same reason; the complete want of suggestion of the so-called simple sensations by the asserted complex ones.

. . . .

"From these premises it would seem the easiest possible step to conclude the non-existence of yellow as a primary colour. But this conclusion I am unable to admit in the face of the facts (1) that a yellow ray incapable of prismatic analysis into green and red, may be shown to exist, both in the spectrum and in flames in which soda is present; and (2) that neither red nor green, as sensations, are in the remotest degree suggested by that yellow in its action on the eye.

"Whether under these circumstances the vision of normal-eyed persons should be termed trichromic or tetrachromic, seems an open question."—*Proceedings* of the Royal Society vol x 1850-60 n 70—W P

[1] Such a circle has been published by Chevreul, but the colours are arranged somewhat differently, the antagonistic ones not being opposite to each other.—W. P.

[2] In technical language mixtures of a colour with white are called *tints*; with black, *shades*; but this nomenclature is imperfect, according to the author's view, as the various nuances are considered by him to contain black and white together—W. P.

The luminosity of a pure colour will thus be $= \frac{1}{2}$, and if mixed with an equal quantity of white, it will be

$$= \frac{1 + \frac{1}{2}}{1 + 1} = 0{\cdot}75;$$

that of pure white being 1.

After these preliminary explanations the author proceeds to develop the chief features of his theory of colour-sensation, adopting the principles previously laid down as applicable to black and white only. He expresses the chief points in two propositions:—

1. There are six fundamental sensations of the visual substance, arranged in three pairs. These are—

Black and white.
Blue and yellow.
Green and red.

2. Each of these pairs corresponds to a dissimilation process and an assimilation process of a special kind, so that the visual substance is subject to chemical change, or change of matter, in a threefold way.

The three kinds of change may be either connected or independent; the latter is the simplest supposition, and the author finds it convenient to assume that there are *three different components* of the visual substance, which he considers as corresponding with the three pairs of sensation, and which may, in short, be spoken of as the black-white, the blue-yellow, and the red-green substances respectively.

These three substances are not all present in equal quantities; the black-white one is much more richly provided in the visual organs than either of the others, and the latter are not present in equal amount.

As in the black-white substance, both dissimilation and assimilation go on, the former corresponding to the white and the latter to the black sensation; so the same processes take place in the two other substances, but with much less activity, whence the weight of the six fundamental sensations is very unequal; relatively great in the black and white; relatively less in the four colours. The author does not venture to pronounce which of a pair of colours corresponds to the D and which to the A action.

All rays of the visible spectrum have a dissimilating action on the black-white substance, but the different rays in different degrees. On the blue-yellow or the red-green substance certain rays alone have a D action, certain others an A action, and certain others no action at all. Thus each of the three substances has, so to speak, its own particular sensation-spectrum; and in the actual impression of the spectrum these three overlap or intersect each other.

The spectrum of the black-white substance is the brightest in the yellow, and diminishes on both sides.

The spectrum of the blue-yellow substance consists of two parts, one yellow and one blue, which are separated by a spot which is lightless for this substance; this is the place of the pure green.

The spectrum of the red-green substance consists of three parts, one green in the middle, and one red at each end, giving two spots which are lightless for this spectrum, *i.e.*, the place of the pure yellow and that of the pure blue.

Thus the total spectrum of the visual substance has three distinguished physiological points, where, in addition to the white, only one fundamental colour is visible, viz., yellow, green, or blue. The real red is very small in the spectrum, for the spectral red contains much yellow. The first part of the spectrum from red to pure yellow is thus a mixture of white, red, and yellow; the second, from yellow to green, is a mixture of white, yellow, and green; the third, from green to blue, of white, green, and blue; the fourth, from blue to the end, of white, blue and red. In the pure yellow, green, and blue, only these colours mixed with white are seen.

Mixed light appears colourless, when it acts, on the blue-yellow or the red-green substance, with equal D and A power, for then both effects neutralise each other and the action on the black-white substance alone appears. For this reason two objective kinds of light, which, when mixed, give white, are not *complementary* but *antagonistic;* they do not produce the white by their combination, but merely destroy each other and leave visible the white which was already there.

The *excitability* (*Erregbarkeit*) may vary, doubly, on each of the three substances in the same manner as before explained, so that one and the same objective light-mixture may not only appear lighter or darker, but varying in colour according to the proportions present of the six kinds of excitability, giving various conditions (*Stimmungen*) of the visual organ.

Suppose the eye to have been long at rest, so as to be in what has been called the neutral condition (the D and A-actions being equal in regard to all three of the visual substances), the total sensation will comprise the two opposite colour-sensations of each colour-substance, as well as the white and black sensation, but the latter will be much the stronger, and more predominant, as each of the colour-sensations will neutralise its opposite one, *i.e.*, the red and green will neutralise each other, and so will the yellow and blue. This neutralising effect, however, does not take place in regard to the black-white substance, because the assimilation causing the black sensation is not produced by any direct rays; if there were any solar rays causing A-action in the black-white substance, then solar light might, under certain conditions, be invisible, like an equal mixture of blue and yellow, or red and green. Hence the resulting total sensation, when the eye is at rest, is the mixture of white and black, called neutral gray.

Now if, in this condition, we allow the light of any one of the simple spectral colours, say green, to fall on the eye, it strengthens the already present green sensation, and also the white one. The result is a mixed sensation, formed of green, with a considerable mixture of white, and also with some mixture of black, already existing in the neutral gray. Thus it is that even the spectral colours never appear pure, but always obviously contain white and black impurity.

Pigmental colours are still more impure, as they reflect mixed light, in which only certain rays are more or less weakened. To the colour-action of those rays which are hereby unneutralised by antagonistic rays, is added not only the action of such rays on the black-white substance, but also the action of the whole remaining neutral mixed light which only acts on the black-white sensation.

Mixed light which gives us a beautiful colour-impression may, if colourless light be added, appear entirely or nearly colourless, because the original colour-sensation is already mixed largely with colourless light. Even the spectral colours quickly lose their force and become pale and whitish, when the vision is steadfastly fixed for a time on one of the dark lines, for the excitability of the colour-substance is quickly lowered, while that of the black-white sensation retains its power.

In general the conditions are very unfavourable, in ordinary vision, for the powerful production of colour; for both on the light and the dark parts the colour-sensations are rendered strongly impure, if not almost entirely suppressed by the black-white action. In the darkened eye, in which the latter has less power, the colour-conditions are more favourable, and hence the after-images are often highly coloured. The most favourable conditions are where the black-white substance has been fatigued by dazzling light, and hence the after-images in such cases often show colours almost more powerful than even those of the spectrum, where, in the original objects, scarcely any colour was appreciable.

It must be always borne in mind that every visual sensation, however it may appear, is really a mixture of all the six fundamental sensations. That one of the six, which has relatively the greatest weight, gives the character and name to the mixed sensation. If any one fundamental sensation is so strong in predominance over all the others, that the latter are not distinguishable, it approaches the idea of purity, which, however, in reality can never exist.

When the visual organ has been for a long time protected from any external stimulus, it assumes, more or less perfectly, that neutral condition in which the assimilation and dissimilation, as well as the D-excitability and the A-excitability are equal for all the three visual substances.

In this state, in order that a mixed light should produce a colourless impression, it is necessary that this light should have an approximately equal assimilating and dissimilating moment, by which is meant the product of the stimulus and the excitability. Such mixed light may be called objectively colourless light.

But the same light will appear, say, greenish, if the red-green substance is no longer in the neutral condition, but has its green excitability greater than that of the red. For in this case the A and D-moments will not be equal, and a small difference will exist to the advantage of the green.

Now when a part of the previously neutrally tuned visual organ has been stimulated by coloured light, the condition of this part will become so altered that the excitability for the perceived colour diminishes and becomes less than the excitability for the opposite colour. Under these circumstances any mixed light which, in the neutral condition appeared colourless, will now appear coloured with the opposite colour. And if a part of the visual organ has been affected, say, by the action of green light, on looking at a blue or yellow surface, the blue or yellow will appear tinged with red.

The phenomena of simultaneous colour-contrast and of colour-induction are explained in the same manner as for the corresponding phenomena in black and white.

It has been seen that by the white illumination of any part of the visual organ, the other parts of it, and particularly those adjoining, are, by the indirect action of the stimulus, darkened; or the sensation of black is intensified; and in a similar way, under the action of coloured light on any part, the sensation of the opposite colour is strengthened in the adjoining parts.

As a consequence of this the relations of excitability are altered; for, according to this theory the sensation of any colour implies also a change of those relations to the disadvantage of this colour and to the advantage of its opposite. If, then, light be allowed to fall on the whole retina, which, under a neutral condition, would be colourless, it now appears coloured; the colour on the previously excited part will be the opposite colour (successive contrast), while that around it will be the same colour as that previously observed (successive induction). In fact, all the phenomena explained for white and black may be, in this way, transferred to the colour-sensation.

The author makes some further remarks on the Young-Helmholtz theory. He admits that the attempt of Young to reduce the great variety of colour-sensations to a small number of physiological variables was a most important step in advance, but he considers that if, as before explained, every psychical result must correspond to some physiological process, the number of fundamental colour-sensations ought, as has been often urged, to be increased to four, and that separate physiological sensations ought to be allotted to white and black. But he considers the great defect of the theory to lie in its only acknowledging *one* kind of excitability, excitation, and fatigue, namely, that which he denotes by D, and that it ignores entirely the antagonistic relations of certain rays to the visual organ; hence it regards the production of white out of "complementary colours" as a result of their mutual combinations, and not of their mutual extinction.

He also remarks on the difficulties of explanation of many phenomena, on this theory, and in particular on the inconsistencies it causes in the attempted explanation of colour-blindness, as shown in the most modern literature on the subject.

In conclusion he gives some remarks on the chief points of his theory, which it may be instructive to repeat here.

The theory, although immediately dictated by a free and unbiased analysis of the visual sensations, is essentially based on certain fundamental principles, taken from the acknowledged phenomena of organic and psychical life, and it is by these principles that the author's views are brought into connection with the doctrines of physiology generally.

With respect to the doctrine of light and colour, the first thing to mention is the natural system of visual sensations, founded on their internal similarity; and further, the grouping of the six fundamental sensations in three pairs of opposite colours.

Next comes, as of fundamental importance, the appreciation of the visual sensations as the psychical correlatives of the nutritive processes, or changes of matter in the visual substance, which leads to the separation of the D and A sensations, and further, to the principle that every D sensation implies a decrease, every A sensation an increase of the visual substance. Corresponding to the three pairs of simple or fundamental sensations are assumed three kinds of D and A processes in the visual substance and three kinds of specific D and A excitability. The colourlessness of mixed light formed out of "complementary" rays, is explained by their antagonistic relations.

Further, here, for the first time the proof is methodically and comprehensively produced that the separate parts of the nervous visual substance are in internal functional changing relationship (*Wechselbeziehung*), which is to be regarded as reciprocally connected with the change of matter; for when $\frac{D}{A}$ is greater on a stimulated part, it is less in the surrounding parts, and *vice versâ*; so that after the stimulus the excitabilities of both parts change in opposite directions.

These propositions and their consequences afford the means of explaining the various phenomena mentioned, but it often happens that several explanations are possible for one and the same phenomenon, and that the decision between them must be reserved for more detailed inquiry. What we immediately appreciate in a visual sensation is the ratio of the corresponding D and A processes to each other, for this determines the *quality* of the sensation. A change of sensation gives only an indication of the change of this ratio, and not of the changes of its two components. Then it is that we have so often the choice between an increase of assimilation and a stoppage or decrease of dissimilation, and *vice versâ*. But the theory itself gives means of determining these, by further and more detailed and intricate investigations; and the author promises future communications by which the details will further be supplied, without as he hopes, any material alteration of the principles he has laid down.

WILLIAM POLE

THE "PARASOL" ANTS OF TEXAS: HOW THEY CUT AND CARRY LEAVES: ORIGIN OF CASTES BY EVOLUTION

IN Mr. McCook's recent investigation (NATURE, vol. xx. p. 583, and *Proc.* Acad. Nat. Sci. Phil., 1879, p. 35) he stated that he observed carefully both the mode of cutting and the system of carrying cut portions of oak-leaves at Camp Wright, and at a vegetable garden near Austin, Texas.

To investigate successfully he found it best to thrust